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Perception and Control of Locomotion

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Over the past four years we have been studying problems of control and coordination with funds from AFOSR. Work over the first three years has been reviewed in the final report for the original AFOSR award (Flach, 1996). This report reviews work for the last year of the ASSERT grant. This work has focused on perception and control of low altitude flight. Experimental work from two synthetic task environments is described in this report. The first environment involved descent to low altitude. The key independent variables were speed of forward motion and optical texture (dot, grid, splay, depression). Results showed an interaction between texture and speed. For textures that contained depression information, the rate of approach to asymptote decreased with increasing forward speed. This was not true for splay texture. These results are consistent with previous experimental work and support the signal-to-noise hypothesis (Flach, Hagen, & Larish, 1992). The second environment involved collision avoidance. The key independent variables were speed of approach and the climb dynamics. The results showed that subjects were sensitive to both the dynamic constraints and uncertainties associated with action. Performance curves approached the optimal performance boundaries in state space. The buffer between the optimal boundary and the performance curves was proportional to the variability of responses. These two studies illustrate an active psychophysics paradigm that focuses on perceptual-motor coordination within closed-loop control tasks. The results are consistent with the logic of optimal control models that incorporate both dynamic constraints and uncertainty (perceptual and motor noise) as critical components in the model of the human operator.

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Perception and Control of Locomotion

Contents

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Abstract

Over the past four years we have been studying problems of control and coordination with funds from AFOSR. Work over the first three years has been reviewed in the final report for the original AFOSR award (Flach, 1996). This report reviews work for the last year of the ASSERT grant. This work has focused on perception and control of low altitude flight. Experimental work from two synthetic task environments is described in this report. The first environment involved descent to low altitude. The key independent variables were speed of forward motion and optical texture (dot, grid, splay, depression). Results showed an interaction between texture and speed. For textures that contained depression information, the rate of approach to asymptote decreased with increasing forward speed. This was not true for splay texture. These results are consistent with previous experimental work and support the signal-to-noise hypothesis (Flach, Hagen, & Larish, 1992). The second environment involved collision avoidance. The key independent variables were speed of approach and the climb dynamics. The results showed that subjects were sensitive to both the dynamic constraints and uncertainties associated with action. Performance curves approached the optimal performance boundaries in state space. The buffer between the optimal boundary and the performance curves was proportional to the variability of responses. These two studies illustrate an active psychophysics paradigm that focuses on perceptual-motor coordination within closed-loop control tasks. The results are consistent with the logic of optimal control models that incorporate both dynamic constraints and uncertainty (perceptual and motor noise) as critical components in the model of the human operator.

List of Figures

1.0 General Overview

This is a final report for an ASSERT grant which was an addendum to an earlier AFOSR grant. A final report for the original award, titled "Perception/Action: An Holistic Approach II," was submitted last year (November 1995). That report summarizes the initial three year period of the research. This report will discuss progress made over the last year.

1.1 General Framework

Our general approach to the problem of control of locomotion (and in particular the control of low level flight has been characterized as "active psychophysics" (Flach, 1990; Flach, 1993; Flach & Warren, 1995; Warren, 1988; Warren & McMillan, 1984). This approach takes a holistic perspective on the problem of controlling perception and action. Whereas, many psychophysical programs depend on open-loop tasks so that the experimenter can have precise control of stimulation, an active-psychophysical approach studies performance in the context of closed-loop coordination tasks. In an active-psychophysical paradigm the stimulus is under the control of the subject. In this paradigm the pattern of stimulation varies as a function of the subject's actions within a synthetic task environment. Instead of manipulating stimulation, the experimenter sets constraints on the dynamics of action, the structure of information (feedback), or performance objectives and costs (goals). These constraints function as the independent variables. Performance is evaluated in terms of time domain and frequency domain measures that have been traditionally used to characterize the performance of control systems. In various phases of the research these have included RMS error, correlated control power, the asymptote and rate of approach to a fixed target, and RMS control velocity. The active psychophysical approach is illustrated in Figure 1.

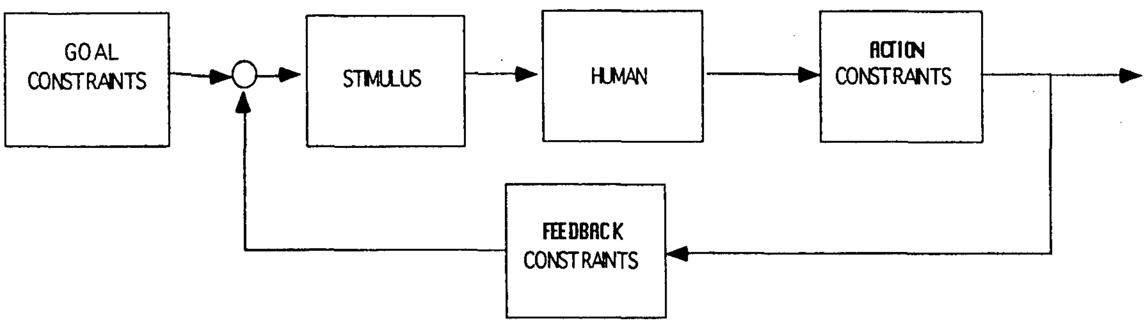

Figure 1. In studying coordination within a closed-loop system the experimenter manipulates goal, action, and feedback constraints, rather than the stimulus. The stimulus at any moment is a function of the responses of the subject.

This is a basic research program with the primary goal of discovering fundamental properties of human perceptual-motor coordination. The active psychophysical paradigm has evolved from our struggles to find an appropriate balance between external and internal validity in our basic research program.

We feel that this framework improves the external validity of our research program over more traditional psychophysical approaches. It does this without compromising the internal validity that is essential to basic research. We hope that the basic questions that we ask within this approach will be representative of the problems that humans face in natural environments (such as low altitude flight). Further, we hope that the principles and answers that are discovered will help to inform the design of effective human-machine systems.

2.0 The Control of Locomotion

Detailed reports of our studies on control of locomotion are contained in two Masters Theses (Kelly, 1993; Garness, 1995) and in a paper that is in press in the *Journal of Experimental Psychology: Human Perception & Performance* (Flach, Warren, Garness, Stanard, & Kelly, In press). This work has also been described in the final report for the original AFOSR award (Flach, 1995). Two experiments will be summarized in this report. The first experiment examined approach to a low altitude flight path as a function of optical texture and forward speed. The second experiment examined collision avoidance as a function of the dynamic flight capabilities of the vehicle.

2.1 How Low Can You Go?

Since Gibson, Olum, and Rosenblatt (1955) first described structural properties of optic flow fields, numerous experimental programs have tried to empirically validate the link between the geometry of the flow field and control of action. Researchers such as Anderson (Anderson & Braunstein, 1985), Cutting (1986), Owen (Owen & Warren, 1987), and Warren (Warren, Mestre, Blackwell, & Morris, 1991) have utilized graphic computer displays to simulate and manipulate the structure of optical flow fields and to measure the consequences for perception and action. Warren and Wertheim (1990) summarize much of the work in reference to the control of locomotion and Flach and Warren (1995) reviews work related to control of low altitude flight. Our research, extends this work to examine perception and control of altitude.

Our earlier report to AFOSR (Flach, 1995) provided detailed geometric analyses of the optical flow field with respect to the altitude control problem. That report also summarizes the experimental literature that has addressed the problem of altitude control. This information is also available in numerous published reports (Flach, Hagen, & Larish, 1992; Flach & Warren, 1995; Flach, Warren, Garness, Stanard, & Kelly, In press). Our interest in this work was motivated by a controversy over whether splay (the angle at which lines parallel to the line of motion converge at the horizon) or depression angle (the angle of texture elements below the horizon) provided the best information for controlling altitude. Figure 2 shows displays that isolate these two sources of optical information.

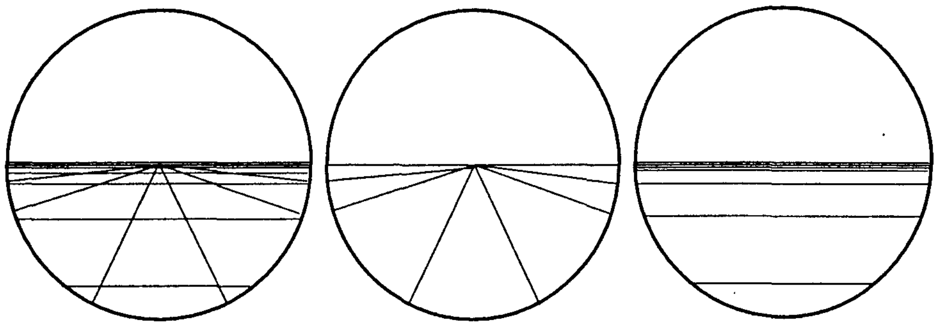

Figure 2. Three types of ground textures that have been used to isolate the components of optic flow associated with change of altitude.

Table 1: Source of Optical Activity

SIGNAL **NOISE**

TEXTURE	Altitude	Fore-aft	Lateral
GRID	$-\left(\frac{\dot{z}}{z}\right)\cos S \sin S$ $-\left(\frac{\dot{z}}{z}\right)\cos \delta \sin \delta$	$\left(\frac{\dot{x}_g}{z}\right)\cos^2 \delta$	$\left(\frac{\dot{Y}_g}{z}\right)\cos^2 S$
DOT	$-\left(\frac{\dot{z}}{z}\right)\cos S \sin S$ $-\left(\frac{\dot{z}}{z}\right)\cos \delta \sin \delta$	$\left(\frac{\dot{x}_g}{z}\right)\cos^2 \delta$	$\left(\frac{\dot{Y}_g}{z}\right)\cos^2 S$
DEPRESSION	$-\left(\frac{\dot{z}}{z}\right)\cos \delta \sin \delta$	$\left(\frac{\dot{x}_g}{z}\right)\cos^2 \delta$	
SPLAY	$-\left(\frac{\dot{z}}{z}\right)\cos S \sin S$		$\left(\frac{\dot{Y}_g}{z}\right)\cos^2 S$

Based on our analysis of the literature and our previous experimental work (see Flach, 1995), we hypothesized that the relative utility of these texture elements might depend on the motion context. Previous research that had shown superior performance with splay texture had generally been conducted in the context of fixed wing vehicles and had involved high speed forward motion. Research that had shown superior performance with depression texture had been done in the context of rotorcraft and had involved low levels of or no forward motion. Our "signal-to-noise" hypothesis suggested that the ability to detect optical changes due to altitude change might depend on the levels of optical activity resulting from other motions (e.g., forward movement). Table 1 shows how various motions would effect the levels of optical activity. Signal refers to optical activity that specifies change in altitude. Noise refers to optical activity that is not a function of altitude change. Note particularly, that forward motion is a source of noise for depression texture, but not for splay texture.

2.1.1 The synthetic task environment

Our previous experimental work (e.g., Flach, 1995) found support for the signal-to-noise hypothesis in the context of an altitude tracking task where subjects were required to maintain a constant altitude resisting disturbances due to quasi-random wind gusts. Here we will summarize a study using an alternative task. For the current task, the subjects were to perform a controlled approach to low altitude from 400 ft. They were instructed to attain an altitude as low as possible as quickly as possible, avoiding collision with the ground. The simulated vehicle had simple first order dynamics and control was restricted to altitude. The independent variables were texture (Grid, Dot, Splay, or Depression) and speed (0, 35, or 70 ft/s). Texture was manipulated within subjects and speed was a between subjects factor. Dependent measures included the rate of approach and the final asymptote level. The rate of approach and asymptote level were derived from fits of the time histories to an exponential model of approach. This fit is illustrated in Figure 3 which shows actual time history data for a subject and the model fit to the data. The equation for the model was:

$$altitude = (400 - a) \times e^{-r(t-k)} + a$$

where a is the asymptote, r is the rate of approach, t is time, and k reflects delays in initiating the descent response. Values for these parameters were derived based on a non-linear least squares fit to subjects' time histories for each trial from the final experimental session (Day 3). For the trial shown in Figure 3: a = 16.61, r = .2238, and k = 8.114. This model provided very good fits for most of the time histories.

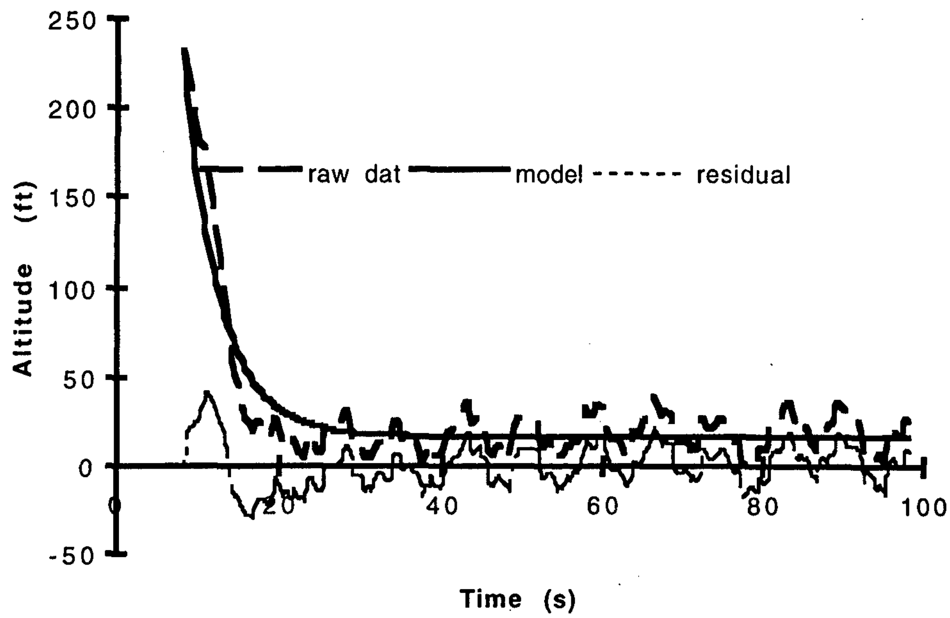

Figure 3. A sample of a typical time history (altitude in ft as a function of time in s) (dotted line) with the exponential model ($altitude = (400 - a) \times e^{-r(t-k)} + a$) (solid line) for approach to the surface. Values for the model parameters were (a = 16.61, r = .2238, k = 8.114).

2.1.2 Summary of Key Results

The mean value for the rate of exponential approach to the surface was .2348 (SD = .0412). At this rate of approach subjects would be within 3.5 ft of an asymptotic level of approximately 25 ft from the initial altitude of 400 ft in approximately 20 s. The rate data for the last session were analyzed using a 3 x 4 mixed design analysis of variance. An interaction between texture and forward speed was significant ($F(6,382) = 2.37$, $p=.029$, $\eta^2 = 3.00$), as shown in Figure 4. This interaction is consistent with the signal-to-noise hypothesis. For all textures containing depression information (grid, dot, depression) the rate of approach was highest for the lowest flow rate and lowest for the higher flow rate. Thus, when altitude information was difficult to pick-up due to optical noise at high flow rates then the approaches were more cautious or conservative. The rate of approach for splay was essentially independent of forward speed. This has important implications for theories of optic flow. Detecting and utilizing an optical invariant for control of locomotion is not a simple case of yes (I see it!) or no (I don't). The pick-up of information is a graded function that depends on the salience of the optical activity specific to the control dimension relative to the optical activity that is not correlated with the control variable.

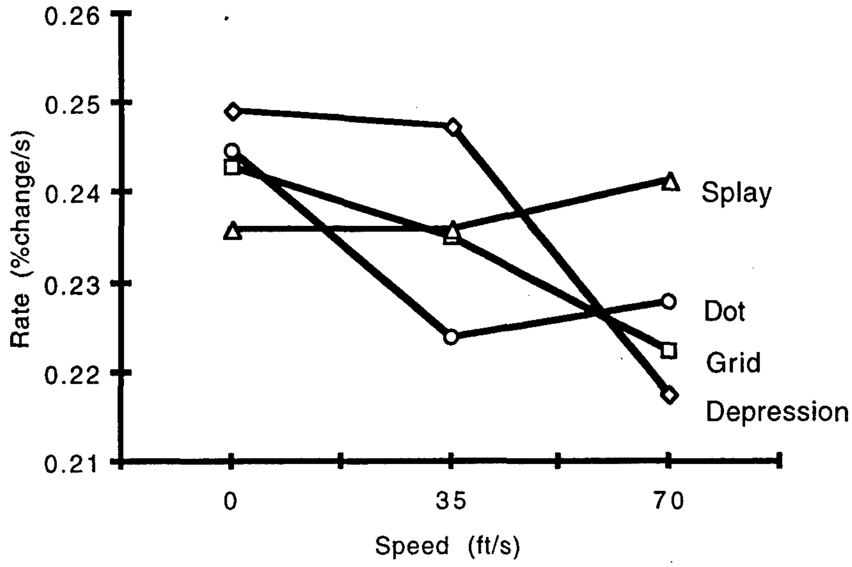

Figure 4. Significant interaction between texture type (grid, dot, depression, splay) and flow rate (0, 35, or 75 ft/s) for the rate of approach to asymptote.

2.2 Control of Collision

The critical independent variables for the altitude control task (e.g., texture) reflected constraints on information or feedback in the control task. This section considers the constraints on action. Whereas, optical structure may specify distance to a surface, the significance of a particular distance depends critically on the capacity for action. How low is too low? How close is too close? The answers to these questions depend upon the maneuvering capabilities of the vehicle. For a high performance aircraft with small time constants the boundary between safe and unsafe margins of approaches will be different than for a larger, more sluggish aircraft. Thus, for coordinated control it is not sufficient that the pilot can judge distances adequately, but those distances must be judged in terms of their implications for action. We consider this ability to see the world in terms of the appropriate actions as a fundamental element of situation awareness. This section will discuss recent analyses of data that were presented in the previous AFOSR report (Flach, 1995). A more detailed report of this research can be found in Stanard, Flach, and Smith (1996).

2.2.1 The Synthetic Task Environment

The synthetic task environment is illustrated in Figure 5. At the start of the task the vehicle was moving toward a cliff at a particular velocity. The subject had a discrete (button switch) control that was used to initiate ascent. The subjects' task was to initiate ascent at the last possible moment so that the vehicle just passed over the edge of the cliff, narrowly avoiding collision. The two critical independent variables were the ascent dynamics and the approach

velocity. For half the subjects (Constant Ascent Group) the climb rate was constant, independent of forward velocity. To do the task successfully, this group would have to initiate ascent farther from the cliff face when moving at high velocities than when moving at slower velocities. For the second half of subjects (Proportional Ascent Group) the climb rate was proportional to velocity. That is, at higher velocities the vehicle would climb at a higher rate. The consequence of this dynamic was that the optimum position for initiating the ascent was independent of velocity. The subject could initiate climb at a fixed distance from the cliff independent of the forward velocity. Figure 6 shows the boundaries set by these two dynamics. For the Constant Ascent Group the optimal distance from the cliff increases with increasing velocity. For the Proportional Ascent Group the optimal distance is constant.

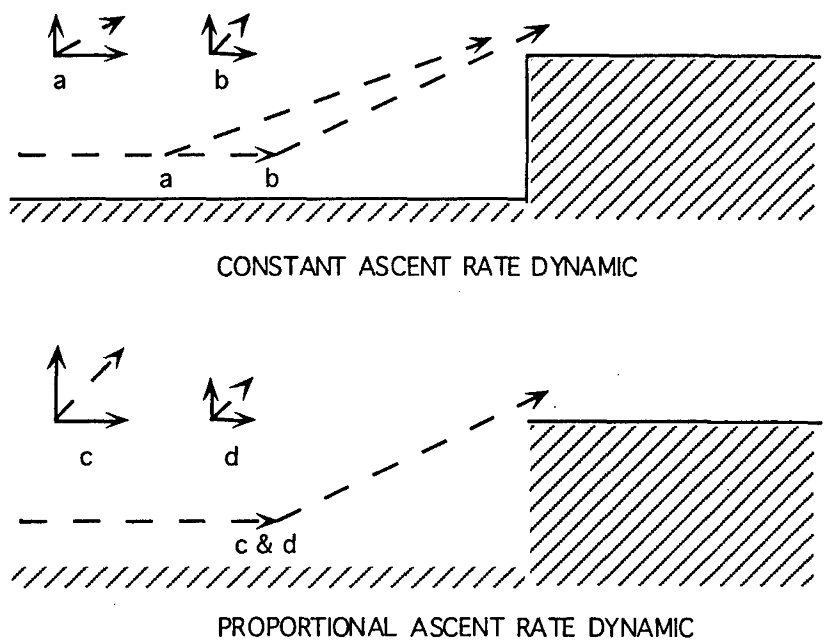

Figure 5. These diagrams illustrate the consequences of the two different dynamic constraints. For the constant ascent rate dynamic, ascent rate is constant. Thus, to just clear the cliff the pilot must initiate the climb farther from the cliff when the forward velocity is greater (a) than when it is lower (b). For the proportional ascent rate dynamic, ascent rate is proportional to forward velocity. The result of this is that the pilot must initiate ascent at the same position, independent of whether forward velocity is high (c) or low (d).

2.2.2 Summary of Key Results

Figure 6 shows performance for trained operators. Note that this figure takes the form of a state space diagram. The pattern of data within this state space (a significant interaction between dynamic and velocity) suggests that the subjects were sensitive to the different action boundaries for the two dynamics. The Constant Ascent Group began ascent at distances that increased with

increasing velocity. The slope of this function was very similar to that of the optimum boundary. The Proportional Ascent Group also began ascent at farther distances with increased velocities. However, the slope of this function was much shallower than for the Constant Ascent Group --- approaching the zero slope of the optimal boundary.

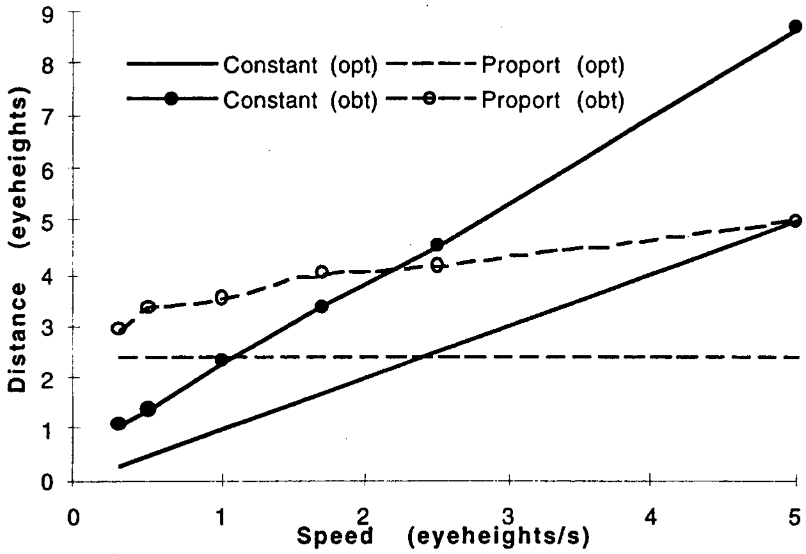

Figure 4. The solid line represents optimal performance for the constant ascent rate dynamic. The dotted line represents *opt*imal performance for the proportional ascent rate dynamic. The filled circles show actual *obt*ained performance for subjects trained with the constant ascent rate dynamic. The open circles show actual performance for subjects trained in the proportional ascent rate dynamic.

The data show that differences in performance for the two groups were consistent with the boundaries defined by their particular vehicle dynamics. However, performance is not at the limits defined by those boundaries. There is a buffer between the measured performance and the boundary and this buffer increases with increasing speed. This is true for both conditions. What is the significance of this buffer?

Recently, we tested the hypothesis that the buffer might reflect action variability. Every act is affected by motor noise. Such variability can be clearly seen in research using simple motor tasks (e.g., Fitts, 1954; Schmidt, Zelasnik, Hawkins, Frank, & Quinn, 1979) and has been incorporated into optimal control models of human tracking behavior (e.g. See Sheridan & Ferrell, 1974). The amount of noise appears to scale with dynamic properties of the movement. For example, Schmidt, et al. (1979) modeled the variability as an increasing function of movement speed. A recent model by Flach, Guisinger, and Robison (In press) models the variability as an increasing function of movement acceleration.

For simple target acquisition tasks the variability is typically assumed to be normally distributed about the intended target. However, Worringham (1991) has recently found that when a hard constraint is placed on a target boundary (i.e., subjects are highly penalized for crossing it) subjects appear to adjust their aim point to avoid contact with that boundary. The subjects appear to aim in front of the target a distance that is proportional to the movement variability. If variability is increased (due to the speed or distance of the movement) the aim point is adjusted accordingly. In this way, the subject avoids the penalties associated with the hard constraint. In our experiment the cliff functions as a hard constraint. Thus, it seems reasonable that subjects might maintain a buffer that reflects their control variability (or response noise); so that, the noise does not result in crashing into the hard boundary on some proportion of the trials.

To test this theory of motor variability, the size of the buffer between the optimal state boundary and actual performance was correlated with the variance at each point. A strong correlation was found for both conditions ($R^2 = .92$ for the variable ascent rate condition; and $R^2 = .84$ for the constant ascent rate condition). It appears as if response variability increased with speed. Further, the subjects appear to be sensitive to this increased variability and appear to adjust their performance accordingly. Thus, the buffer reflects a speed-accuracy trade-off that minimizes the probability of crashing into the cliff. In optimizing performance the subjects are sensitive to both the dynamics of the vehicle and the variability of their perception-action system. These two aspects of optimization have been explicitly modeled in optimal control models of the human controller.

3.0 General Summary

How humans deal with uncertainty (noise or information) has been a central question for theories of human information processing. The high correlation between performance and uncertainty as measured using information statistics was an important discovery that led to the formulation of information processing models of human behavior. However, the information processing paradigm has placed such emphasis on statistical variability that they have largely ignored the specific properties of stimulation that arises from structural and dynamic properties of environments. Optic flow is one such structural property that information processing theories have largely ignored. More recently, ecological approaches to human performance have focused on the specificity of structural properties of the environment, such as optical invariants. However, this approach tends to overlook the uncertainties and variances associated with the pick-up of information and the execution of actions.

Optimal control theory provides a principled basis for arguing that uncertainty and specificity are both important factors shaping the coordination of perception and action. The research reported here provides empirical support

for that argument. The active psychophysical perspective provides a context within which to appreciate the contributions of both traditional information processing approaches and ecological approaches to human performance. Basic theories of human performance need to address both the uncertainties and the specificities involved in the coordination problem.

An important aspect of the active psychophysical approach is the use of synthetic environments for measuring performance. A synthetic environment is an experimental context that simulates both the specificities and the uncertainties found in natural settings. One advantage of the synthetic environment is that these specificities and uncertainties can be manipulated and unconfounded within the synthetic environment in ways that are not possible in the natural setting. The separation of splay and depression information in the altitude study is one example. This permits the control necessary for rigorous hypothesis testing. The second advantage of synthetic environments is that the structure in the synthetic environment provides a semantic link to the natural environment that is often lost in the nonsense tasks that have been the hallmark of traditional behavioral research since the time of Ebbinghaus. The synthetic environment provides a context for addressing semantic issues (meaning) related to human performance (Flach, 1996). We hope that this approach will lead to a basic science that has both internal and external validity.

4.0 Publication Activity *(This includes activities for the full 4 years spanned by the original AFOSR award and the ASSERT addendum)*

Masters Theses:

Allen, B. (1993). *Dynamic occlusion as information for object recognition: The effects of observer mode uncertainty.* Unpublished Master Thesis, Wright State University, Dayton, OH.

Hutton, R. (1993). *The role of activity in the perception of three dimensional objects from dynamic occlusion.* . Unpublished Master Thesis, Wright State University, Dayton, OH.

Kelly, L. (1993). *Altitude control and the interaction of global optical flow with ground texture type.* . Unpublished Master Thesis, Wright State University, Dayton, OH.

Brickman, B. (1994). *The effects of noise and temporally delayed sensory feedback on perception/action coupling.* . Unpublished Master Thesis, Wright State University, Dayton, OH.

Garness, S. (1995). *Global optical flow and altitude control: Resolving the signal-to-noise ratio hypothesis.* . Unpublished Master Thesis, Wright State University, Dayton, OH.

Robison, A. (1995). *Distance perception: A comparison of methods.* . Unpublished Master Thesis, Wright State University, Dayton, OH.

Holden, J. (1996). *Perceptual-motor coordination in an endoscopic surgery simulation.*. Unpublished Master Thesis, Wright State University, Dayton, OH.

Journal Articles and Book Chapters:

Holden, J.G. & Flach, J.M. (Under review). Perceptual-motor coordination in an endoscopic surgery simulation. *Journal of Experimental Psychology: Applied*

Flach, J.M. & Holden, J. (Under review). The reality of experience: Gibson's way. *Presence*

Flach, J.M. (Under review). Ready, fire, aim: Toward a theory of meaning processing systems. In D. Gopher & A. Koriat (Eds.). *Attention & Performance XVII.*

Flach, J.M. & Rasmussen, J. (Under review). Cognitive engineering: Designing for situation awareness. In N. Sarter & R. Amalberti (Eds.) *Cognitive Engineering in the Aviation Domain.* Mahwah, NJ: Erlbaum.

Bennett, K.B., Nagy, A.L., & Flach, J.M. (In press). Visual displays. In G. Salvendy (Ed.). *Handbook of Human Factors.* Mahwah, NJ: Erlbaum.

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Published Conference Proceedings:

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Holden, J.G. & Flach, J.M. (1996). Hand-eye coordination in an endoscopic surgery simulation. *Third Annual Symposium on Human Interaction with Complex Systems.* (pp. 110-115). Los Alamitos, CA: IEEE Computer Society Press.

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Flach, J.M. (1995). Maintaining situation awareness when stalking cognition in the wild. *Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness.* (pp. 25-34) Daytona Beach, FL: Embry-Riddle Aeronautical University.

Dominguez, C.O., Hutton, R.J.B., Flach, J.M. & McKellar, D.P. (1995). Perception-Action coupling in endoscopic surgery: A cognitive task analysis approach. In B.G. Bardy, R.J. Bootsma, & Y. Guiard (Eds.) *Studies in Perception and Action III.* (pp. 285 -288). Mahwah, NJ: Erlbaum.

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Garness, S.A., Flach, J.M., Stanard, T. & Warren, R. (1994). The basis for the perception and control of altitude: Splay & depression angle components of optical flow. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.* (p. 1275 - 1279). Santa Monica: The Human Factors and Ergonomics Society.

Hutton, R.J.B., Flach, J.M., Brickman, B.J., Dominguez, C.O., Hettinger, L., Haas, M., & Russell, C. (1994). Keeping in touch: Kinesthetic-tactile information and fly-by-wire. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.* (p. 26 - 30). Santa Monica: The Human Factors and Ergonomics Society.

Flach, J.M. (1994). Beyond the servomechanism: Implications of closed-loop, adaptive couplings for modeling human-machine systems. *Proceedings of the '94 Symposium on Human Interaction with Complex Systems.* (p. 401 - 406). Greensboro, NC: Industrial Engineering Department, North Carolina A & T.

Kelly, L. Flach, J.M., Garness, S. & Warren, R. (1993). Altitude control: Effects of texture and global optical flow. *Proceedings of the Seventh International Symposium on Aviation Psychology.* Columbus, OH.

Flach, J.M. & Bennett, K.B. (1992). Graphical interfaces to complex systems: Separating the wheat from the chaff. *Proceedings of the Human Factors Society 36th Annual Meeting.* Santa Monica, CA: Human Factors Society. (pp. 470-474).

Flach, J.M. & Hancock, P.A. (1992). An ecological approach to human-machine systems. *Proceedings of the Human Factors Society 36th Annual Meeting.* Santa Monica, CA: Human Factors Society. (pp. 1056-1058).

Conference Presentations Publication of Abstract Only:

Dominguez, C., Dexter, D., Dunn, M., Flach, J. & McKellar, D. (1996). Decision making in laparoscopic surgery: Implications for training. *43rd Annual Symposium of the Society for Air Force Clinical Surgeons.* San Antonio (3/31-4/5).

Flach, J.M. (1995). Putting the Human in Control: Toward Use-Centered Design. Invited Tutorial Session *Symposium on Human Interaction with Complex Systems.* Greensboro, NC: Department of Industrial Engineering, North Carolina A & T State University.

Flach, J.M. (1995). Cognitive Ergonomics of complex systems. Panel presentation *Symposium on Human Interaction with Complex Systems.* Greensboro, NC: Department of Industrial Engineering, North Carolina A & T State University.

Dominguez, C.O., Hutton, R.J.B., Flach, J.M., & McKellar, D.M. (1995). Human performance issues in video surgery. Presented at the *Aerospace Medical Association 66th Annual Scientific Meeting.* Anaheim, CA, (May).

Flach, J.M. (1995). Beyond the laboratory: Lessons from human factors. Invited paper presented at the *sixty-seventh Annual Meeting of the Midwestern Psychological Association,* Chicago, IL.

Brickman, B.J. & Flach, J.M. (1994). The effects of delayed sensory feedback on object recognition performance: Uncoupling perception and action. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.* (p. 954). Santa Monica: The Human Factors and Ergonomics Society.

Guisinger, M.A., Flach, J.M. & Robison, A.B. (1994). Fitts' law and the "force" or Newton: A match made in physics. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.* (p. 955). Santa Monica: The Human Factors and Ergonomics Society.

Robison, A.B., Hutton, R.J.B., & Flach, J.M. (1994). The role of action in perception. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.* (p. 955). Santa Monica: The Human Factors and Ergonomics Society.

Flach, J.M. (1993). Meaning a lost dimension. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting.* (p. 1375 - 1376). Santa Monica, CA: The Human Factors and Ergonomics Society.

Flach, J.M. (1993). A constraint-based global perspective on information for control. Presented at the *VIIth International Conference on Event Perception and Action.* University of British Columbia, Vancouver, BC, Canada.

5.0 Participating Professionals

Graduate Students	RA Support	Thesis Completed
Brad Allen	8-90 - 9-91	1993
Bart Brickman	6-92 - 2-95	1994
Thomas Debris		
Cindy Dominguez	AFIT	
Sheila Garness	9-92 - 1-95	1995
Mark Guisinger		
Jay Holden		1996
Robert Hutton	6-92 - 2-95	1993
Leigh Kelly	9 -91 - 6-92	1993
Amy Robison		1995
Matthew Smith		
Terry Stanard	6-94 - 8 - 96	

Undergraduate Students: Jeffery Light; Patty Lake

6.0 Interactions

Presentations:

Flach, J.M. (1996). Human performance: A meaning processing approach. Invited presentation. Waseda University, Tokyo, Japan.

Flach, J.M. (1996). Space-Time: The reality of experience. Invited presentation. Psychology and Computer Science Departments, University of Calgary. (March).

Flach, J.M. (1995). Information: Beyond the communications channel metaphor. Invited presentation to the Psychology Department, Rice University, Houston, TX.

Flach, J.M. (1995). Human factors challenges of minimally invasive surgery. Invited presentation to the Houston Chapter of the Human Factors and Ergonomics Society, Houston, TX.

Flach, J.M. (1995). Keep the horizon steady! The challenges of minimally invasive surgery. Invited presentation to the Tri-State Chapter of the Human Factors and Ergonomics Society. Cincinnati, OH (May 9).

Dominguez, C., Hutton, R., & Flach, J.M. (1994). Coordination of perception and action in video surgery. ERGO EXPO. Dayton, OH. (Sept 20)

Flach, J.M. (1994). Error in adaptive systems: Reconsidering fundamental assumptions about causality. Invited paper presented at the workshop on *Approaches to Modeling the Evolution and Breakdown of Adaptive Systems.* Annual Workshop on New Technologies and Work --- NeTWORK. Bad Homburg, Germany. (June 16 -18)

Flach, J.M. (1994). Going with the flow: Taoism, low altitude flight, and the meaning of life. Invited presentation at the Beckman Center, University of Illinois, Urbana, IL. (April 22)

Flach, J.M. (1994). Fitts' Law: Might the force be with it. Invited presentation to the Kineseology Department, University of Illinois, Urbana, IL. (April 22).

Flach, J.M. (1993). Beyond the servomechanism: Active Psychophysics. Invited presentation Risø National Laboratory, Kognitiv Systemsgruppe, Roskilde, Denmark. (Sept. 3)

Flach, J. M. (1993). Perception and action: A holistic approach. Presentation to the Center for Human Motor Research, Department of Movement Science - Division of Kinesiology, University of Michigan, Ann Arbor, MI. (March 26th).

Flach, J.M. (1993). Perception and Control in Low Altitude Flight. Presentation sponsored by the Purdue Student Chapter of the Human Factors and Ergonomics Society. Department of Industrial Engineering, Purdue University, West Lafayette, IN. (April 2nd).

Flach, J.M. (1992). Perception and Control in Low Altitude Flight. Presentation to the Wright State Student Chapter of the Human Factors and Ergonomics Society. Wright State University, Dayton, OH.

Flach, J.M. (1992). Virtuality: Beyond reality. Presentation to the Ohio Consortium for Virtual Environment Research. Miami Valley Research Park, Dayton, Oh.

Flach, J.M. (1992). Perception/Action: A Holistic Approach. Presentation to the Human Movement Sciences Group, Psychology Department, The Free University, Amsterdam. (Dec).

Flach, J.M. (1992). Ecological approaches to design. Presentation to the Form Theory Group, Department of Industrial Design, Delft Technical University.

Flach, J.M. (1992). Human performance in low altitude flight. Invited lecture *The Tenth Annual International Conference on Aviation Physiology and Training: Human Factors in Aviation Part III.* Southampton, PA: Aeromedical Training Institute (AMTI) A Division of Environmental Tectronics Corporation.

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Fitts, P.M. (1954). The information capacity of the human motor system in controlling amplitude of movement. *Journal of Experimental Psychology*, **9**, 24 - 32.

Flach, J.M. (1996). Situation awareness: In search of meaning. *CSERIAC Gateway*, VI(6), 1- 4.

Flach, J.M. (1995). Perception/Action: An Holistic Approach II. Final report submitted to AFOSR. (Contract F49620-92-J-0511). Bolling Air Force Base, DC.

Flach, J.M. (1993). Active psychophysics: A psychophysical program for closed-loop systems. In E.J. Haug (Ed.), *Concurrent engineering tools and technologies for mechanical system design.* (p. 987 - 993). New York: Springer-Verlag.

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Flach, J.M., Hagen, B.A., & Larish, J.F. (1992). Visual information for the active regulation of altitude. *Perception & Psychophysics*, **51**, 557-568.

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Garness, S. (1995). *Global Optical Flow and Texture: Resolving the Signal-to-Noise Hypothesis*. Masters Thesis: Wright State University.

Gibson, J.J., Olum, P., & Rosenblatt, F. (1955). Parallax and perspective during aircraft landings. *American Journal of Psychology*, **68**, 372-385.

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Owen, D.H. & Warren, R. (1987). Perception and control of self-motion: Implications for visual simulation of vehicular locomotion. In L.S. Mark,

J.S. Warm, & R.L. Huston (Eds.) *Ergonomics and human factors: Recent research*. New York: Springer Verlag.

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Warren, R. & McMillan, G.R. (1984). Altitude control using action-demanding interactive displays: Toward an active psychophysics. *Proceedings of the 1984 IMAGE III Conference*. (pp. 405 -415). Phoenix, AZ: Air Force Human Resources Laboratory.

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Worringham, C.J. (1991). Variability effects on the internal structure of rapid aiming movements. *Journal of Motor Behavior*, **23**, 75 - 85.